FORM PTO-1390 (REV 11-98) U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: 287300022USA

U S APPLICATION NO (If known, see 37 CFR 1 5): 09/424431

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/US98/10389	22 May 1998 (22.05.98)	23 May 1997 (23.05.97)

TITLE OF INVENTION
METHOD AND APPARATUS FOR DELIVERING RADIATION THERAPY DURING SUSPENDED VENTILATION

APPLICANT(S) FOR DO/EO/US
William Beaumont Hospital; WONG, John W.; JAFFRAY, David A. and SHARPE, Michael B.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a **SECOND or SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. [X] This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(l).
4. [X] A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [ ] is transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] has been transmitted by the International Bureau.
   c. [X] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [ ] A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. [ ] Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. [ ] are transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] have been transmitted by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [ ] have not been made and will not be made.
8. [ ] A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. [X] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. [ ] A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. [ ] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. [ ] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [ ] A FIRST preliminary amendment.
    [ ] A SECOND or SUBSEQUENT preliminary amendment.
14. [ ] A substitute specification.
15. [ ] A change of power of attorney and/or address letter.
16. [X] Other items or information: Express Mailing Certificate (Label No. EJ948538252US)
    Article 34 Amendment
    Three (3) sheets of drawings showing Figures 1-7

05/22/2000 PVOLPE 00000116 080750 09424431
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09/424431

U.S. APPLICATION NO (if known see 31 CFR 1 5)	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUUMBER
60/063,454	PCT/US98/10389	287300022USA

42? Rec'd PCT/PTO 23 NOV 1999

17. [X] The following fees are submitted:

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5))

		CALCULATIONS PTO USE ONLY
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO	**$970.00**	
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO	**$840.00**	
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO	**$760.00**	
International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(l)-(4)	**$670.00**	
International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4)	**$96.00**	
ENTER APPROPRIATE BASIC FEE AMOUNT =		$ 670.00
Surcharge of **$130.00** for furnishing the oath or declaration later than [ ] 20 [X] 30 months from the earliest claimed priority date (37 CFR 1.492(c)).		$ 130.00

CLAIMS	NUMBER FILED		NUMBER EXTRA	RATE	
Total claims	20	-20 =	0	**X $18.00**	$
Independent claims	3	-3 =	0	**X $78.00**	$
MULTIPLE DEPENDENT CLAIM(S) (if applicable)				**+$260.00**	$ 0.00
TOTAL OF ABOVE CALCULATIONS =					$ 800.00
Reduction of 1/2 for filing by small entity, if applicable. A Small Entity Statement must also by filed (Note 37 CFR 1.9, 1.27, 1.28).					$
SUBTOTAL =					$ 800.00
Processing fee of **$130.00** for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +					$
TOTAL NATIONAL FEE =					$ 800.00
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +					$ 0.00
TOTAL FEES ENCLOSED =					$ 800.00
				Amount to be: refunded	$
				charged	$

a. [X] A check in the amount of $_____ to cover the above fees is enclosed.

b. [ ] Please charge my Deposit Account No. _____ m the amount of $_____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [X] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 08-0750 A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO

Thomas T. Moga
HARNESS, DICKEY & PIERCE, P.L.C.
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SIGNATURE

Thomas T. Moga
NAME

34,881
REGISTRATION NUMBER

IN THE UNITED STATES RECEIVING OFFICE

Attorney Reference No. 2873000022PC

International Application No.:	PCT/US98/10389
International Filing Date:	22 May 1998
Priority Date:	23 May 1997
Applicant:	William Beaumont Hospital et al.
For:	METHOD AND APPARATUS FOR DELIVERING RADIATION THERAPY DURING SUSPENDED VENTILATION

LETTER OF AMENDMENT UNDER ARTICLE 34 AND RULE 66.3

Hon. Commissioner of Patents
and Trademarks
Box PCT
Washington, DC 20231

Dear Sir:

In response to the International Preliminary Examination Report completed 26 February 1999, please add the following claims to the above-identified PCT application. The addition of these claims is made in accordance with procedures consistent with U.S. patent prosecution practice. In order to facilitate this amendment, replacement page numbers 18, 18a, 18b, and 18c for the International Application are included.

IN THE CLAIMS

Please add new Claim 2 as follows:

2. The method for delivery radiation therapy to a patient during suspended ventilation according to Claim 1, the method including the step of attaching a respiration monitor to the patient through a mouthpiece that includes one or more air flow valves.

Please add new Claim 3 as follows:

3. The method for delivery radiation therapy to a patient during suspended ventilation according to Claim 1, the method including the step of utilizing a computer control to provide a measure of the cyclical expiration and inhalation cycle of the patient.

Please add new Claim 4 as follows:

4. The method for delivery radiation therapy to a patient during suspended ventilation according to Claim 2, the method including the step of operating said one or more air flow valves of said mouthpiece to suspend the patient's breathing at a desired point.

Please add new Claim 5 as follows:

5. The method for delivery radiation therapy to a patient during suspended ventilation according to Claim 4, the method including the steps of halting inhalation and exhalation during the time of suspended breathing.

Please add new Claim 6 as follows:

6. The method for delivery radiation therapy to a patient during suspended ventilation according to Claim 1, the method including repeating said step of suspending patient ventilation at said specific air flow direction and lung volume as necessary to administer repeated radiation doses.

Please add new Claim 7 as follows:

7. The method for delivery radiation therapy to a patient during suspended ventilation according to Claim 1, the method including undertaking CT planning and treatment at a reproducible ventilatory phase.

Please add new Claim 8 as follows:

8. The method for delivery radiation therapy to a patient during suspended ventilation according to Claim 1, the method including the step of applying to the patient a mechanical device for attachment to the patient's nose for temporarily halting air passage therethrough.

Please add new Claim 9 as follows:

9. The method for delivery radiation therapy to a patient during suspended ventilation according to Claim 1, the method including the steps of acquiring CT scans at different respiratory phases.

Please add new Claim 10 as follows:

10 A method for establishing breath-holding reproducibility in a patient for the delivery of radiation therapy, the method comprising the steps of:

identifying a lung volume;

suspending patient ventilation at said lung volume; and

administering radiation therapy during the suspension of patient ventilation.

Please add new Claim 11 as follows:

11. The method for establishing breath-holding reproducibility in a patient for the delivery of radiation therapy according to Claim 10, the method including the step of attaching a respiration monitor to the patient through a mouthpiece that includes one or more air flow valves.

Please add new Claim 12 as follows:

12. The method for establishing breath-holding reproducibility in a patient for the delivery of radiation therapy according to Claim 11, the method including the step of operating said one or more air flow valves of said mouthpiece to suspend the patient's breathing at a desired point.

Please add new Claim 13 as follows:

13. The method for establishing breath-holding reproducibility in a patient for the delivery of radiation therapy according to Claim 10, the method including the steps of halting inhalation and exhalation during the time of suspended breathing.

Please add new Claim 14 as follows:

14. The method for establishing breath-holding reproducibility in a patient for the delivery of radiation therapy according to Claim 10, the method including repeating said step of suspending patient ventilation at said specific air flow direction and lung volume as necessary to administer repeated radiation doses.

Please add new Claim 15 as follows:

15. An apparatus for suspending ventilation in a patient and delivering radiation therapy to the patient during suspended ventilation, the apparatus comprising:

an apparatus for identifying a specific air flow direction and lung volume of the patient;

an apparatus for suspending patient ventilation at said specific air flow direction and lung volume; and

an apparatus for administering radiation therapy during the suspension of patient ventilation.

Please add new Claim 16 as follows:

16. An apparatus for suspending ventilation in a patient and delivering radiation therapy to the patient during suspended ventilation of Claim 15 wherein said apparatus for suspending patient ventilation includes a ventilator assembly having one or more selectively operable valves.

Please add new Claim 17 as follows:

17. An apparatus for suspending ventilation in a patient and delivering radiation therapy to the patient during suspended ventilation of Claim 15 wherein said ventilator assembly includes a t-connector which includes a first one-way valve, a second one-way valve, and a pneumotach.

Please add new Claim 18 as follows:

18. An apparatus for suspending ventilation in a patient and delivering radiation therapy to the patient during suspended ventilation according to Claim 17 further including a computer, said first one-way valve, said second one-way valve, and said pneumotach being operably associated with said computer.

Please add new Claim 19 as follows:

19. An apparatus for suspending ventilation in a patient and delivering radiation therapy to the patient during suspended ventilation according to Claim 18 further including a monitor for providing a readout of cyclical lung volume trace and target respiration level while the patient is breathing, said monitor being operably attached to said computer.

Please add new Claim 20 as follows:

20. An apparatus for suspending ventilation in a patient and delivering radiation therapy to the patient during suspended ventilation according to Claim 15 further including a mouthpiece attached to said ventilator assembly.

REMARKS

The present Letter of Amendment is being submitted in response to the International Preliminary Examination Report completed 26 February 1999.

Claim 1 remains as filed. New Claims 2 through 20 are submitted for consideration at this time. No claims are cancelled. Accordingly, Claims 1 through 20 are pending in this applicatino.

The basis for the new claims may be found throughout the specification and drawings as originally filed. No new matter has been added. Applicants believe that the new claims do not go beyond the disclosure of the application as originally filed.

Replacement sheets 18, 18a, 18b, and 18c are submitted herewith.

Applicants respectfully submit that the application in its present form is allowable over the art of record. Should the Authorized Officer have any questions, Applicants respectfully request that the Officer contact the Applicants' undersigned attorney at (248) 641-1600.

If any fees are due in connection with this response to prevent the abandonment of this application, please consider this an authorization to charge our Deposit Account No. 08-0750 for any fee which may be due. A duplicate copy of this response is enclosed.

The original of this amendment is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" services, and a copy of this amendment is being sent by facsimile to the U.S. Receiving Office on the date

shown below.

Respectfully submitted,

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Attorney for Applicants

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Dated: September 23, 1999

TTM/hs

METHOD AND APPARATUS FOR DELIVERING RADIATION THERAPY DURING SUSPENDED VENTILATION

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to a method and apparatus for delivering radiation therapy. More particularly, the present invention relates to a method and apparatus for delivering radiation therapy during suspended ventilation.

2. Discussion

Radiation for the treatment of cancer embodies a variety of risks related to overexposure to healthy tissue. A major concern in increasing the dose to treat cancer is the potential increase in life-threatening complications. This is particularly the case for treatment in the thoracic and upper abdominal regions. Because of respiratory motion, a large margin is needed to ensure proper tumor coverage, which in turn leads to a large volume of healthy tissue being irradiated. For lung treatment, there is a risk of five percent pneumonitis in five years if the whole lung receives more than 1,750 cGy, two-thirds of the lung receives more than 3,000 cGy, and one-third of the lung receives 4,500 cGy. Similar observations have been made for other sites, such as the treatment of focal lesions in the liver.

There are rather difficult tolerances to satisfy if one wants to increase dose. Take, for example, the traditional radiation treatment using AP/PA

(anterior to posterior/posterior to anterior) beam arrangements for lung treatment. Given, for example, a modest lung thickness of 15 cm. Assuming a total lung capacity of 5.0 liters, the total irradiated lung volume is calculated by taking the lung volume around the tumor and subtracting tumor volume. Given a margin of 3 cm around the tumor that is 7 cm in diameter, 45% of the lung will initially be irradiated. Given a margin of 2 cm, 30% of the lung will be irradiated. Given a margin of 1 cm, 18% of the lung will be irradiated. Given a margin of 0.5 cm, 13% of the lung will be irradiated.

In response to concerns regarding over-exposure, there have been intense efforts over the past decade to implement high dose conformal radiation therapy which have led to the development of many new advanced technologies. These advanced technologies include computed tomographic (CT) simulation, three dimensional (3D) treatment planning, computer controlled medical accelerators, multileaf collimators (MLCs), and electronic portal imaging devices (EPIDs). These technologies are becoming increasingly more common, making possible the implementation of new treatment techniques such as intensity modulated radiation therapy. The success of high dose conformal therapy depends critically on treatment accuracy. With more accurate information about the position of a tumor, a tighter treatment margin can be prescribed such that a higher dose can be delivered to the tumor without increasing deleterious complications.

In practice, the treatment margin must account for the width of the beam penumbra, the daily variation in patient setup, and the variation in organ positions between fractions and during a single fraction. Recent

advances have been made to sharpen beam penumbra, reduce daily setup variation and compensate for inter-fraction variation of organ position. (Intra-fraction organ motion associated with breathing, however, remains problematic.) Intra-fraction variations pertain to the changes in the organ shapes and positions during a single treatment fraction. These include the motion of tumors and organs in the thoracic and abdominal regions. In certain procedures for radiotherapy of the thorax, patient breathing has an effect on the procedure. Motion of the lungs and diaphragm can cause displacement of organs and a tumor being treated. Organs and tumors in the thorax and abdomen are known to move by more than 2 cm during the breathing cycle. At present, the 3D imagings used for treatment planning are "static". They do not contain information about the changing tumor positions while the patient breathes. Consequently, a wide margin is used, irradiating a large volume of critical tissue. As a result, limits are placed upon the dose that can be delivered to the tumor. Concern for pulmonary complications has constrained radiation therapy of lung cancer, despite the dismal prognosis of the disease. High dose conformal therapy in the thorax and abdomen is more effective when organ motion due to breathing can be minimized.

There have been different approaches to minimizing respiratory motion. One approach is to have the patient shallowly breathe pure oxygen. Another approach has been through a technique known as "triggering" or "gating" in which the respiration cycle is monitored using an external device such as a spirometer or a string-gauge to turn on the beam only at a certain point in the respiration cycle. A possible component of this technique is to train the

patient to exercise the breath-holding at the appropriate lung volume in order to extend the duty cycle of the beam. A further approach is to use deep inspiration breath holding, during which time the beam is activated.

The optimal delivery of gated or "breath-hold" therapy requires the 3D characterization of dynamic organ and tumor motion such that both beam geometry and "gate" can be optimized. However, this optional approach is not possible with most gated therapy proposals which rely on 2D fluoroscopy. It is also difficult to obtain gated 3D CT scans because of the complexity in machine control. Deep inspiration breath hold can be applied, but the 3D CT scan can only be made in one respiratory position. It is possible that dynamic 3D tomographic images can be made with the Immatron (an ultrafast CT specifically built for cardiac scanning) or using a fast MRI. However, the former approach is prohibitively expensive, while the latter approach produces distortions and complex image fusion is required to provide 3D images.

Accordingly, current approaches to gated therapy rely exclusively on the passive monitoring of respiration, followed by electronic or manual triggering of the beam. However, electronic triggering requires control of the medical accelerator to coordinate with passive respiratory monitoring. This is not readily achieved. On the other hand, manual gating requires the patient to reproducibly get to the same respiratory position. Inevitable variability means that a wider tolerance would need to be set. In addition, the radiation needs to be turned off immediately when the breath-hold creeps out of tolerance. Failure to do so can be serious since gated therapy is likely to employ higher dose rates.

While the above techniques represent various advances in the art, all known methods and devices for the delivery of radiation therapy during suspended ventilation are subject to improvement.

SUMMARY OF THE INVENTION

The method and associated apparatus of the present invention involves attaching a respiration monitor to a patient through a mouth piece that includes air flow valve(s). Computer control provides a measure of the cyclical expiration and inhalation cycle of the patient. When a desired point in the respiration cycle point is reached by the patient, the mouthpiece valve(s) is/are operated to suspend or "freeze" patient breathing at the desired point. In other words, all air flow through the mouth piece is stopped at the desired point. While the valve(s) is/are closed, the patient cannot inhale or exhale. In some cases, several cycles of this breath "freezing" can be used to administer the desired therapeutic radiation dosage. Since the clinician controls the point at which breath freezing occurs, the patient does not have to produce a repeated breathing state. This approach also does not require a complex interconnection between the respiration monitor and radiation therapy equipment. The system is well suited for low cost implementation with a minimal need to interface with the radio therapy manufacturers and equipment.

It is a principal object of the present invention to provide a method and an apparatus which overcome the drawbacks associated with the prior art, including but not limited to those discussed above.

It is another object of the present invention to provide a method and apparatus for eliminating inaccuracy encountered during diagnosis and therapy attributable to movement of body organs resulting from normal breathing.

It is a more specific object of the present invention to provide a method and apparatus for the delivery of radiation therapy during periods of suspended ventilation.

It is another object of the present invention to provide a method and apparatus which allows for CT planning and treatment at a reproducible ventilatory phase.

The above and other objects are achieved in accordance with the principles of the present invention in a method and apparatus for delivering radiation therapy during suspended ventilation.

In one form, the present invention provides a method to suspend ventilation of a patient for the delivery of radiation therapy. The method includes the general step of identifying a specific air flow direction and lung volume. Additionally, the method of the present invention includes the general step of suspending patient ventilation at the specific air flow direction and lung volume. Further, the method of the present invention includes the general step of administering radiation therapy during the suspension of patient ventilation.

BRIEF DESCRIPTION OF THE DRAWINGS

Additional objects and advantages of the present invention will become apparent from a reading of the following detailed description of the preferred embodiments which makes reference to the drawings of which:

Figure 1 is a schematic representation of an active breathing control apparatus embodying the present invention for suspending ventilation for purposes of administering radiation therapy;

Figure 2 is a stylized view showing the active breathing control apparatus of the present invention in operative association with a supine patient;

Figure 3 is a top view of an apparatus constructed in accordance with the teachings of the present invention;

Figure 4 is a graph plotting air flow and lung volume versus time including a period of suspended ventilation for the delivery of radiation therapy;

Figure 5 is a schematic of an alternate embodiment of the apparatus of the present invention;

Figure 6 is a stylized view showing the alternative embodiment of the active breathing control apparatus of the present invention shown in Figure 5 in operative association with a supine patient; and

Figure 7 is a simplified flow chart illustrating the general steps of the method of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to Figure 1, a schematic diagram of an active breathing control apparatus 10 constructed in accordance with the teachings of the present invention is shown.

The active breathing control apparatus utilizes a ventilator assembly 13. (A suitable ventilator for modification is commercially available from Siemens.) As shown, the apparatus has two "scissors" valves 14 and 16 to monitor and control inhalation and exhalation independently. During normal operation, one of the valves 14 or 16 is always closed while the other is open. With the modifications made pursuant to the present invention, the scissors valves 14 and 16 are interfaced to a personal computer (PC) (not shown). The signals are processed to display the changing lung volume during the breathing cycle. A software utility is implemented to allow the user to specify (1) the point in the breathing cycle for closing both valves 14 and 16, and (2) the duration of the active breath-hold.

The patient 12 is interconnected to the modified ventilator assembly 13 through a subassembly 18 which includes a t-connector 19 which includes a first one-way valve 20 and a second one-way valve 21, a pneumotach 22 and a mouthpiece 23. A first tube 24 connects the scissor valve 14 and a second tube 25 connects to the other scissor valve 16. A nose clip 26 is used to prevent ventilation through the nose. Alternatively, the mouthpiece and nose clip 26 can be replaced by a face mask.

The valves 14 and 16 as well as the pneumotach 22 are connected to a computer 28 which selectively drives each element according to a selected operations program.

Figure 2 illustrates the apparatus of the present invention in relation to a supine patient 12. The ventilator assembly 13 is illustrated in its approximate position in relation to the patient 12. Optionally, a mirror 30 is provided at an angle such as a 45 degree angle for the view of the patient 12. A monitor 32 is preferably provided outside of the treatment room for the operator, while a smaller monitor 34 (or LCD) is optionally provided for viewing by the patient. The monitors 32 and 34 provide a means of continuously displaying the cyclical lung volume trace and the target respiration level while the supine patient is breathing. (The displays need not present the same information.) Each of the monitors 32 and 34 is operatively associated with the computer 28. An abort switch 36 may also be provided for operation by the patient 12 to turn off the radiation machine and open the valve 14 in the event of discomfort.

Figure 3 illustrates is the arrangement of the "scissors" valves 14 and 16 of the active breathing control apparatus 10 within the ventilator assembly 13.

Figure 4 shows the real-time display of the airflow and lung volume for a normal subject during normal breathing. An active breathing control level is also shown.

Figure 5 illustrates an alternate embodiment of the active breathing control apparatus of the present invention. According to this embodiment, a

control apparatus 50 is shown. The apparatus includes a single valve 52 and a pneumotach 54 to monitor and control inhalation and exhalation. The valve 52 and the pneumotach 54 are connected to a computer 55 via lines 56 and 58. The pneumotach 54 is also fluidly connected to a carbon dioxide remover 60 and a millipore filter 61. The carbon dioxide remover 60 may be of the "soda lime" reservoir type, although this is not intended as being limiting.

Figure 6 illustrates the apparatus 50 in operative association with a supine patient 12'. The patient 12' is provided with a noseclip 26.A mouthpiece 13' is used for ventilation. The fluid line 62 is connected with the millipore filter 61 via the fluid tube 62. Optionally, a mirror 64 is provided at an angle such as a 45 degree angle for the view of the patient 12'. A monitor 66 is preferably provided outside of the treatment room for the operator, while a smaller personal monitor (or LCD) 68 is optionally provided for viewing by the patient. Both the monitor 66 and the personal monitor 68 are operatively associated with the computer 55. An abort switch 70 may also be provided for operation by the patient 12' to turn off the radiation machine and open the valve 52 in the event of discomfort.

In comparison to the two valve system set forth previously, the single valve is simpler to operate. However, the two valve system allows the provision of oxygen to the patient via the valve 14. The single-valve modification also avoids the excessive piping used and significantly shortens the length of tubing, thereby greatly reducing the dead-space where air can be compressed. This modified design also improves the precision of volume measurements.

An apparatus is thus provided which allows for the maintenance of breath-holding reproducibility while being as non-intrusive to the patient as possible. In general operation, and the patient lies in a supine position on a rigid surface table-top. Breathing through the nose is restricted by the nose-clip. One end of the bi-directional pneumotachnometer is connected to the patient via the mouthpiece while the other is connected to the scissors valve (one or two valves, depending on the embodiment) which controls airflow. Airflow to and from the patient passes through a "soda lime" reservoir to remove exhaled carbon dioxide in the apparatus of the present invention. Adopting standard respiratory care procedures, a millipore filter is preferably used as a barrier against air-borne contaminants. To ease patient burden, the patient is allowed to nose breathe after each sequence of maneuvers which takes no more than 5 minutes.

Regardless of the embodiment, the apparatus is calibrated for flow and volume measurements based on acceptable hospital standards. The output of the pneumotachnometer is interfaced with a Pentium class PC. The flow signal is processed to calculate the changing lung volume during breathing in real-time. Operation of the scissor valve(s) is done under computer control. Software utilities are implemented to allow the user to select the lung volume and flow direction for closing the valve(s). A separate "arming" utility is engaged and allows the user to specify a time delay for activating the system. For example, zero time delay means that the valve is closed at the immediate next instance when the pre-selected parameters are met. A six-second time delay means adding six seconds to the zero time delay. This

utility helps coordinate application of the apparatus of the present invention for those radiation machines that operate with a short warm-up prior to beam on, such as a CT scanner or an accelerator such as the Elekta-Philips SL-20.

For each patient, an operating reference needs to be reestablished to set the desired respiratory phase for the apparatus. The functional residual capacity (FRC) of the lungs at the end of normal expiration is chosen because it is the most stable lung volume during normal breathing. At FRC, the lungs are at a natural resting position with neutral pressure. At the start of each session, the supine patient will first go through a period of normal breathing to establish a stable breathing pattern. After that, the volume signals at FRC are averaged for one minute, equivalent to 12 to 15 breathing cycles, and then set as the "zero volume reference." With this zero reference, lung volumes at either inspiration or expiration can be specified for the method of the present invention. Provided that the patient has not moved between maneuvers, the zero reference only needs to be established once.

During an initial training session using the present apparatus, the period of active breath hold that can be comfortably maintained by each individual patient is determined. The period is used for subsequent CT scanning and treatment, but is adjusted as necessary. When the supine patient breathes in and out through the apparatus of the present invention, the cyclical lung volume trace and the target level is displayed continuously on a monitor for the user outside of the treatment room. Inside the treatment room, the patient is shown a similar display and the countdown of the breath-hold period via an angled mirror (such as a 45 degree angle). The patient is

also optionally provided with an "abort" switch to turn off the radiation machine and open the valve of the apparatus in case of discomfort. Verbal communication with the patient is maintained throughout the procedure.

Turning now to Figure 7, the method of the present invention for delivering radiation therapy during suspended ventilation will now be described with particular reference to the apparatus itself. Figure 5 is a flow chart illustrating the general steps of the present invention. The method of the present invention includes three general steps.

In a first step 100, a specific air flow direction and lung volume are identified. This identification is conducted with CT scans taken at different phases of suspended ventilation.

In a second step 200, patient ventilation is suspended at the specific air flow direction and lung volume. Ventilation suspension is accomplished by closing the valves. The patient is preferably alerted to impending ventilation suspension to avoid panic.

In a final general step 300, radiation therapy is administered during suspension of patient ventilation. It may be desirable to incorporate mechanisms to discontinue therapy in the event that the patient desires ventilation.

By using the apparatus of the present invention together with the provided method, the positions of the immobilized organs documented in the planning CT can be reproduced during treatment. The treatment margin can therefore be appropriately reduced, enhancing the potential to escalate dose with conformal therapy. Theoretically, CT scans can be acquired according

to the present invention at different respiratory phases. The information can then be analyzed to determine an optimal phase for treatment in terms of the separation of the tumor from other critical organs. A 3D organ "movie" can then be produced for evaluation. However, in practice, it is more important to find a respiratory phase which is most comfortable for the patient to maintain repeated breath-hold during treatment using the present invention and described method. Accordingly, as a default, the expiratory phase near tidal volume is selected, i.e., when the patient begins to exhale after taking in a normal breath. This respiratory phase was preferred by the patients in the preliminary studies, particularly for the longer period of breath-hold. Expiration is chosen because it involves mostly passive lung recoil and may offer some reproducibility advantages. It is anticipated that radiation therapy will be administered over an extended period of days. Generally speaking, the patient, upon returning for treatment, will receive radiation treatments at the previously identified flow direction and lung volume. In certain applications, it may be desirable to conduct follow-up diagnosis to confirm the location of the area identified for treatment.

Example

The following example illustrates the application of the above-described method and apparatus according to the present invention.

Feasibility studies based on CT scanning have been performed on patients with tumors in the thorax and abdomen. Helical CT scans were acquired at different pre-specified phases of the breathing cycle. The same procedures were repeated for a few patients a week to 10 days later. Lung patients could maintain comfortably an active breath-hold of 15 seconds near the end of normal inspiration. When suspended ventilation was applied during deep inspiration, the breath-hold period ranged from 25 seconds to 50 seconds. The suspended ventilation scans had minimal motion artifacts that were common in the planning CT acquired during quiet breathing with a helical scanner. Lung volumes from repeat suspended ventilation scans acquired at the same phase of breath-hold were within 5% of each other. Similar results were observed for the positions of the liver.

Thus, the present invention provides a method and apparatus for suspending ventilation which provides enhanced specificity of diagnosis and treatment.

CLAIMS

We claim:

1. A method for delivering radiation therapy to a patient during suspended ventilation, the method comprising the steps of:

identifying a specific air flow direction and lung volume;

suspending patient ventilation at said specific air flow direction and lung volume; and

administering radiation therapy during the suspension of patient ventilation.

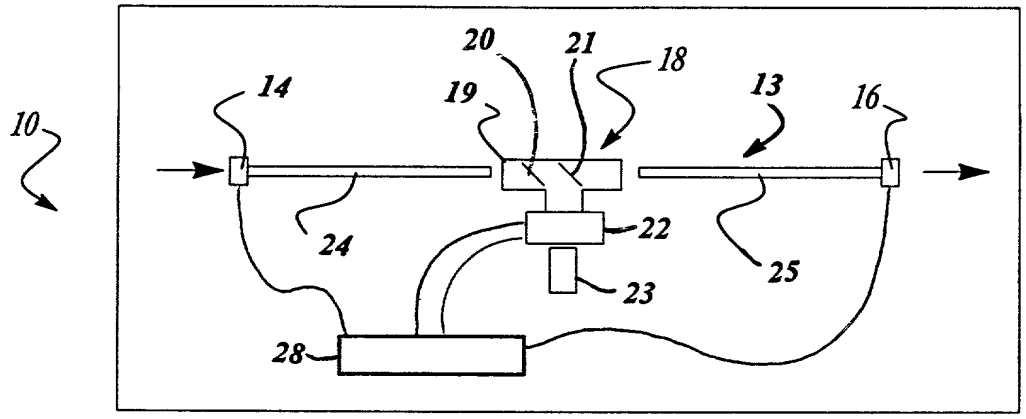

Fig. 1

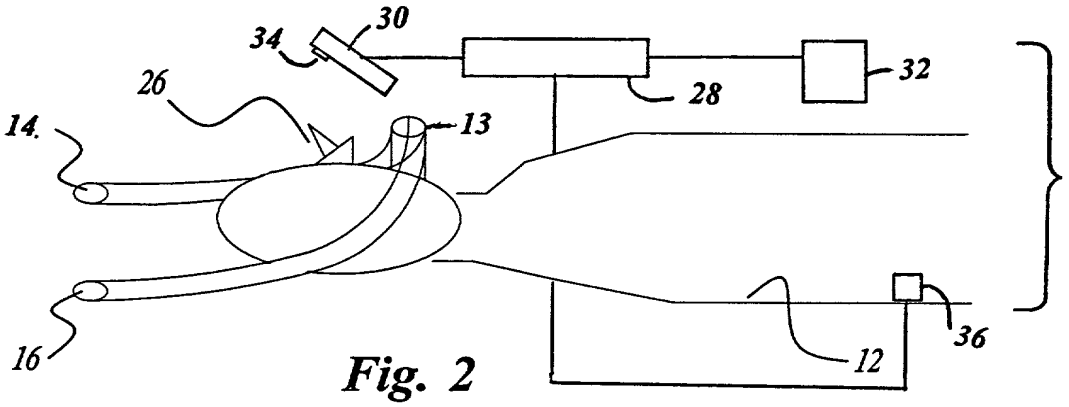

Fig. 2

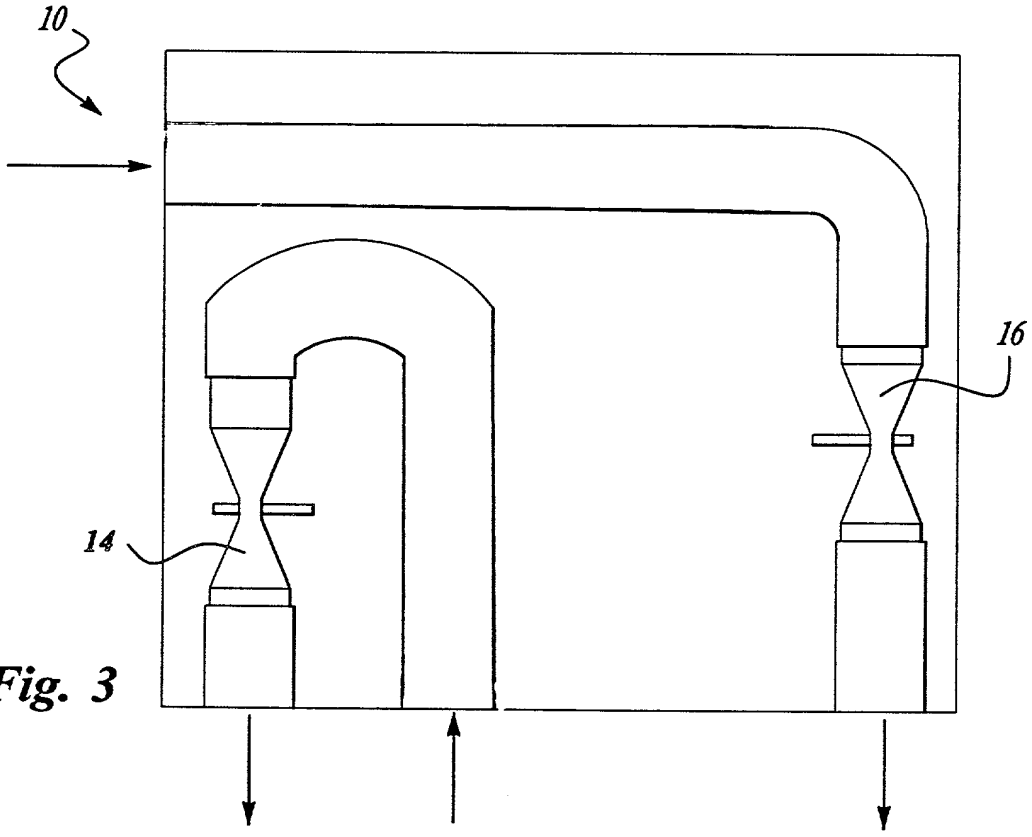

Fig. 3

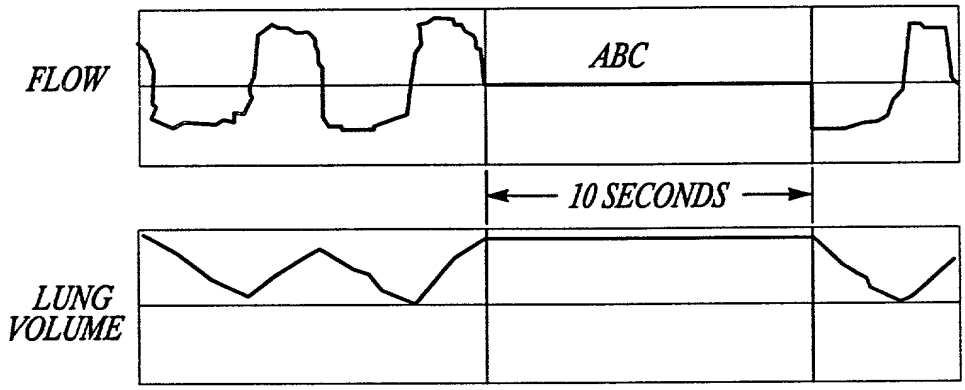

Fig. 4

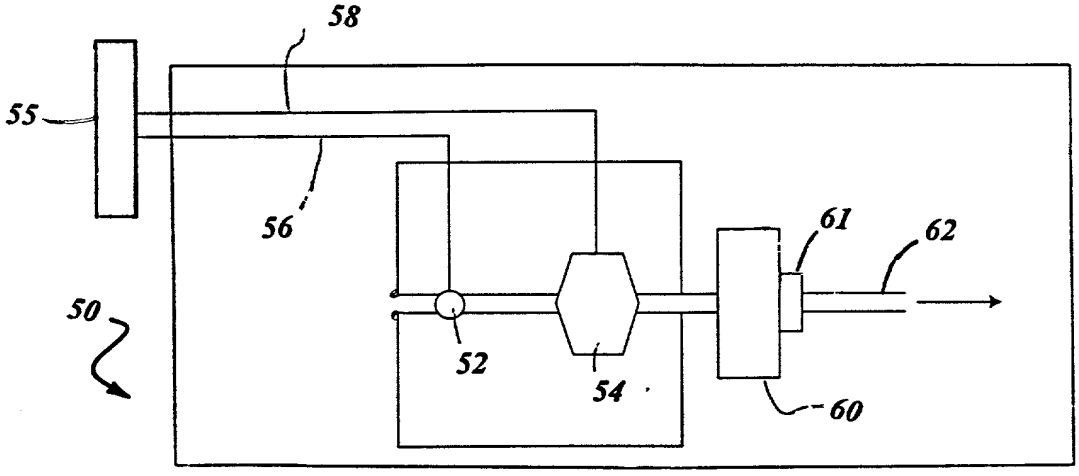

Fig. 5

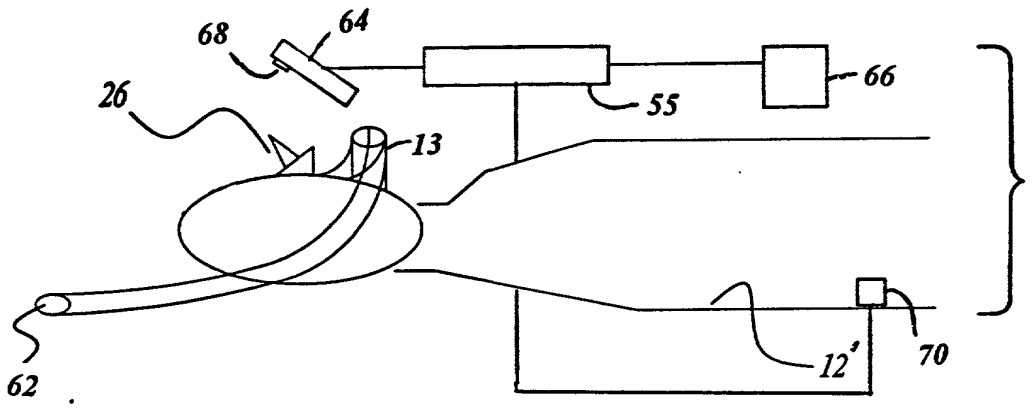
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Fig. 6

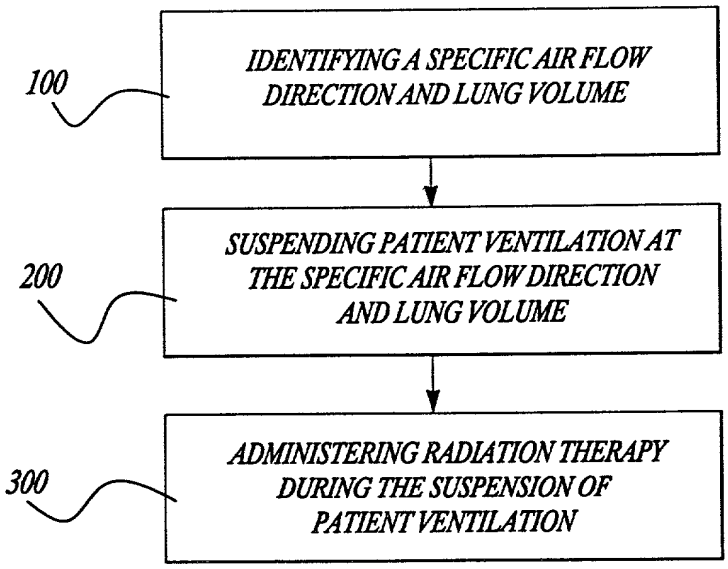

100
IDENTIFYING A SPECIFIC AIR FLOW DIRECTION AND LUNG VOLUME
200
SUSPENDING PATIENT VENTILATION AT THE SPECIFIC AIR FLOW DIRECTION AND LUNG VOLUME
300
ADMINISTERING RADIATION THERAPY DURING THE SUSPENSION OF PATIENT VENTILATION

Fig. 7

Attorney Docket No. 287300022USA

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

METHOD AND APPARATUS FOR DELIVERING RADIATION THERAPY DURING SUSPENDED VENTILATION

the specification of which (check one)

[ ] is attached hereto.

[X] was filed on November 23, 1999 as Application Serial No. 09/424,431 and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information that is material to the patentability of the invention claimed in this application, or information that is material to the examination of this application, in accordance with Title 37, Code of Federal Regulations, section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, section 119(a)-(d) of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

PRIOR FOREIGN APPLICATION(S)

			Priority Claim	
PCTUS9810389	PCT	22 May 1998	X	
(Number)	(Country)	(Day/Month/Year filed)	Yes	No
(Number)	(Country)	(Day/Month/Year filed)	Yes	No
(Number)	(Country)	(Day/Month/Year filed)	Yes	No

DECLARATION AND POWER OF ATTORNEY

I hereby claim the benefit under Title 35, United States Code, §119(e) of any United States Provisional application(s) listed below:

PRIOR PROVISIONAL APPLICATIONS

60/063,454 (application serial number)	May 23, 1997 (Month / Day / Year filed)
_____ (application serial number)	_____ (Month / Day / Year filed)

I hereby claim the benefit under Title 35, United States Code, section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, section 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, section 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

Application Serial No.	**Filing Date**	**Status - patented, pending, abandoned**

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

I hereby appoint Thomas T. Moga, Reg. No. 34,881, and each principal, attorney of counsel, associate and employee of Harness, Dickey & Pierce, P.L.C., who is a registered Patent Attorney, my attorney with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith. I request the Patent and Trademark Office to direct all correspondence and telephone calls relative to this application to Harness, Dickey & Pierce, P.L.C., P. O. Box 828, Bloomfield Hills, Michigan 48303 (248) 641-1600.

Full name of sole or first inventor: John W. Wong

Inventor's signature: _____

Date: Feb. 14, 2000

Residence: 726 Tennyson Downs Court, Bloomfield, Michigan 48304 MI

Citizenship: United States of America

Post Office Address: same as residence

DECLARATION AND POWER OF ATTORNEY

2W

Full name of second joint inventor, if any: David A. Jaffray

Second Inventor's signature: [signature]

Date: 17 February 2000

Residence: 2476 Lincoln Road, Windsor, Ontario, CANADA N8W 2R7

Citizenship: Canada CA

Post Office Address: same as residence

3W

Full name of third joint inventor, if any: Michael B. Sharpe

Third Inventor's signature: [signature]

Date: 14 FEB 2000

Residence: 2066 Vimy Avenue, Windsor, Ontario, CANADA N8W 1P3 CA

Citizenship: Canada

Post Office Address: same as residence

4W

Full name of fourth joint inventor, if any: John R. Musselwhite

Fourth Inventor's signature: [signature]

Date: 17- FEB-2000

Residence: 1814 Hebert, Tecumseh, Ontario N8N 4J4 CA

Citizenship: Canada

Post Office Address: same as residence

Full name of fifth joint inventor, if any: _____

Fifth Inventor's signature: _____

Date: _____

Residence: _____

Citizenship: _____

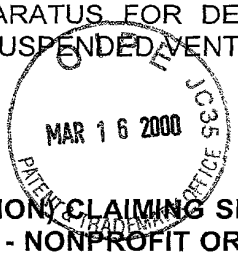
Post Office Address: _____

16 MAR 2000
09/424431

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s) or Patentee: John W. Wong, David A. Jaffray and Michael B. Sharpe
Serial or Patent No.: 09/424,431
Filed or Issued: November 23, 1999
For: METHOD AND APPARATUS FOR DELIVERING RADIATION THERAPY DURING SUSPENDED VENTILATION

Attorney Docket No.: 2873-000022/USA



VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) and 1.27(d)) - NONPROFIT ORGANIZATION

I hereby declare that I am an official empowered to act on behalf of the nonprofit organization identified below:

NAME OF ORGANIZATION: **WILLIAM BEAUMONT HOSPITAL**

ADDRESS OF ORGANIZATION: 3601 West 13 Mile Road
Royal Oak, Michigan 48073-6769

TYPE OF ORGANIZATION:

[ ] University or other institution of higher education
[X] Tax exempt under Internal Revenue Service Code (26 USC 501(a) and 501(c)(3))
[ ] Nonprofit scientific or educational under statute of state of The United States of America

(Name of state: _____)

(Citation of statute: _____)

[ ] Would qualify as tax exempt under Internal Revenue Service Code (26 USC 501(a) and 501(c)(3)) if located in The United States of America
[ ] Would qualify as nonprofit scientific or educational under statute of state of The United States of America if located in The United States of America

(Name of state: _____)

(Citation of statute: _____)

I hereby declare that the nonprofit organization identified above qualifies as a nonprofit organization as defined in 37 CFR 1.9(e) for purposes of paying reduced fees under section 41(a) and (b) of Title 35, United States Code with regard to the invention entitled **METHOD AND APPARATUS FOR DELIVERING RADIATION THERAPY DURING SUSPENDED VENTILATION** by inventors **John W. Wong, David A. Jaffray** and **Michael B. Sharpe** described in

[ ] the specification filed herewith
[X] application serial no. 09/424,431 filed November 23, 1999
[ ] patentno._____issued_____

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) AND 1.27(d)) - NONPROFIT ORGANIZATION

I hereby declare that rights under contract or law have been conveyed to and remain with the nonprofit organization with regard to the above-identified invention.

If the rights held by the nonprofit organization are not exclusive, each individual, concern or organization having rights to the invention is listed below* and no rights to the invention are held by any person, other than the inventor, who could not qualify as an independent inventor under 37 CFR 1.9(c) if that person had made the invention, or by any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

*NOTE: Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)

NAME: _____

ADDRESS: _____

_____

[ ] Individual [ ] Small Business Concern [ ] Nonprofit Organization

NAME: _____

ADDRESS: _____

_____

[ ] Individual [ ] Small Business Concern [ ] Nonprofit Organization

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

Name of Person Signing: Thomas R. McAskin

Title in Organization: Director of Legal Affairs

Address of Person Signing: 3601 West 13 Mile Road, Royal Oak, Michigan 48073-6769

Signature: _____ Date: 2/18/00